MÖSSBAUER MINERALOGY OF CALCINED MURCHISON METEORITE:

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INTRODUCTION

The three Antarctic meteorites B7904, Y82162, and Y86720 are unusual because they have characteristics in common with both CI and CM groups and because they apparently underwent thermal alteration after hydrous alteration on their parent body [e.g., 1,2]. They are also spectrally similar (visible and near-IR) to C, G, B, and F asteroids, which may imply that the surface materials on those asteroids may have undergone thermal alteration [3]. Based on the reflectance spectra of samples of Murchison (CM2 carbonaceous chondrite) that were thermally altered in the laboratory (cryopumped and initial 10^{-5} atm H_2), [3] concluded that putative thermal alteration occurred at temperatures of 600 to 1000°C. [4] have done similar experiments on Murchison and reported mineralogical changes based on data from transmission electron diffraction microscopy, electron diffraction, and analytical electron microscopy. We report here the Mössbauer mineralogy of the same samples of thermally-altered Murchison analyzed by [1,3]. Mössbauer mineralogy gives the molar distribution of Fe among its oxidation states and iron-bearing mineralogies.

RESULTS AND DISCUSSION

The Mössbauer spectra of the Murchison samples are shown in Figure 1. Mössbauer parameters of spectral components used to do spectral fits are given in Table 1. Relative areas of these components as a function of calcination temperature are summarized in Table 2. Three major changes occur in iron oxidation state and/or mineralogy between unheated and 400°C samples, 500 and 600°C samples, and 900 and 1000°C samples.

The RT-400 change results from thermal decomposition of phyllosilicates, which are the dominant iron-bearing phases in Murchison. Oxidation also occurred (Figure 2), and some magnetite formed. The D3 doublet in Murchison is associated with tochilinite [4], which is a sulfide-hydroxide. There is no obvious evidence for a phase with iron chemically bound to sulfur in either the 400 or 500°C samples, unless a low-spin Fe^{2+} phase contributes to D7; in this case the fraction of Fe^{3+} is overestimated in Figure 2 for the 400 and 500°C samples. The 500-600 change is marked by a dramatic increase in the proportion of Fe^{2+}; all samples calcined at temperatures are more reduced than unheated Murchison. The most obvious mineralogic change associated with this transition is the high proportion of iron associated with olivine (40 and 60% at 600 and 700°C, respectively). Troilite (FeS) and pyroxene are also present; magnetite is not present. The unidentified phase associated with D9 has Mössbauer parameters similar to those for tochilinite (D4) in Murchison and may thus may be a Fe^{2+}-Fe^{3+} phase where iron is chemically bound to sulfur. The proportion of the D9 phase decreases in the interval 600-900°C, and is not present after the 900-1000 change. The 900-1000 change is also characterized by the appearance of Fe^0. The 34.0 T value of B_{hf} for Fe^0 implies that it is alloyed with Ni^0 and/or Co^0 [6].

When using these results to constrain the temperature of metamorphism in meteorites and asteroids, it is important to consider whether kinetic effects are important. In particular, does the 500-600 change, where the iron mineralogy changes from relatively oxidized to relatively reduced (Figure 2), just reflect the temperature at which the H_2 gas and/or carbon (intrinsic to Murchison) become reactive on the time-scale of our experiments (~1 wk), imposing reducing conditions? Longer experiment times might to lower the temperature for the 500-600 change, which would lower the temperature below 600°C required for the putative metamorphism of B7904, Y82162, Y86720, and C, G, B, and F asteroids [3] under reducing conditions.

References: [1] Paul and Lipschutz, *Z. Naturf.*, 44A, 979, 1989; [2] Ikeda, *NIPR Symp.*, 5, 49, 1992; [3] Hiroi et al., *Science*, 261, 1016, 1993; [4] Akai, *NIPR Symp.*, 5, 120, 1992; [5] Fisher and Burns, *LPSC24*, 489, 1993; [6] Greenwood and Gibb, *Mössbauer Spectroscopy*, 1971.

Table 1. Preliminary Mössbauer parameters (293K; relative to Fe metal) and phase assignments for spectral components.

	IS (mm/s)	QS (mm/s)	B_{hf} (T)	Oxidation State: Mineralogy
Doublet Components				
D1	1.11	2.58		Fe^{2+}: Phyllosilicate
D2	1.03	1.83		Fe^{2+}: Phyllosilicate
D3	0.33	0.99		Fe^{3+}: Phyllosilicate
D4	0.58	0.72		$Fe^{2+,3+}$: Tochilinite
D5	1.16	3.00		Fe^{2+}: Olivine
D6	1.16	1.80		Fe^{2+}: Unknown
D7	0.38	0.98		Fe^{3+}, low-spin Fe^{2+} (?): Unknown
D8	1.16-1.20	2.26-2.40		Fe^{2+}: Pyroxene
D9	0.53-0.66	0.68-0.49		$Fe^{2+,3+}$: Unknown
Sextet Components				
S1	0.75	-0.17	31.2	Fe^{2+}: Troilite
S2				Fe^{3+}: Magnetite-tet
S3				$Fe^{2+,3+}$: Magnetite-oct
S4	0.02	-0.01	34.0	Fe^{0}: Fe-Ni metal alloy

Table 2. Mössbauer mineralogy (% relative spectral area of iron in iron-bearing phases). There is also evidence for some pyrrhotite in the 600, 700, and 800°C samples.

Temp.	D1	D2	D3	D4	D5	D6	D7	D8	D9	S1	S2 +S3	S4
RT	32	10	33	23	2							
400					4	13	76			1	5	
500					4	20	66			1	9	
600					41			20	28	4	7	
700					61			16	12	11		
800					62			13	8	18		
900					62			15	5	17		
1000					42			19		17		22